Helium Effects on Microstructural Evolution in Tempered Martensitic Steels: In Situ Helium Implanter Studies in HFIR

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Understanding, modeling and managing the effects of high levels of He and dpa on microstructural evolution and properties changes is a primary objective of fusion materials research. A novel in-situ \textsuperscript{58}Ni(n,\alpha) reaction helium-implanter technique was used to characterize the effect of the He/dpa ratio on microstructural evolution and changes in the flow properties of various materials at fusion relevant dpa, dose rates and irradiation temperatures (T\textsubscript{i}). Irradiations in the High Flux Isotope reactor (HFIR) resulted in \textalpha-implantation from thin 1 to 5 \textmu m thick NiAl coatings on TEM discs, producing uniform helium concentration of 5 to 50 appm He/dpa to a depth of 5 to 8 \textmu m. In this study we specifically explore the effect of He/dpa and T\textsubscript{i} on the microstructure of Eurofer97 and F82H in the as-received and cold worked conditions. Crosssection Eurofer97 TEM specimens were examined in a JOEL 2010FE microscope under a variety of imaging conditions. Bubbles were found in the He-implanted region at all three T\textsubscript{i}, with estimated maximum diameters of \approx 10, 6.5 and 2.5 nm at 500°C (\approx 10 dpa and 380 appm He), 400°C (\approx 4.3 dpa and 90 appm He) and 300°C (\approx 4.3 dpa and 90 and appm He), respectively. At the 500°C 10nm faceted cavities were observed, that may actually be voids. The other irradiated microstructures were also characterized, with special emphasis on the association of bubbles with other features. The effects of He/dpa and starting microstructure are examined in detail. Low-load microhardness measurements were used to assess the effects of He/dpa and T\textsubscript{i} on irradiation induced strength elevations. The results are analyzed with a multiscale model described in a companion paper. Another companion paper describes the effects of similar He implantation in nanostructured ferritic alloy, MA957.

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